High mobility metal oxide TFT backplane technology for IT AMOLED display

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Abstract

In this study, we demonstrated the high mobility metal oxide TFTs with small Vth variation and good electrical reliability in Gen. 6 and Gen. 4.5 factory. Moreover, the 13.2 and 12.6 inch AMOLED displays have been successfully developed with amorphous MO-1 and polycrystalline MO-2 backplane technology, respectively.

1. Introduction

Since indium-gallium-zinc oxide (IGZO), an amorphous metal oxide semiconductor material, was first used as the channel layer of TFT, its devices have shown excellent switching characteristics, making amorphous metal oxide TFTs a research hotspot [1]. Amorphous metal oxides represented by IGZO are widely used in driving LCDs and OLEDs due to the advantages such as low manufacturing cost, good large-area uniformity, and low leakage current [2]. Moreover, the LTPO technology combining metal oxide with LTPS has emerged in advanced displays. With the development of large-generation production lines and the demand for reducing costs and power consumption in display panels, metal oxide TFT technology has become a promising candidate for next-generation backplane technology. However, traditional oxide devices' mobility (around 10 $cm^2/V\cdot s$) limits their application in high-resolution and high-refresh-rate displays. Improving device mobility for better performance is the key to expanding the application fields of metal oxides. Recently, research on different metal oxide material systems has increased, the point is adjusting element proportions and doping to optimize material properties [3]. In addition, polycrystalline metal oxide research has also drawn attention. The development of low temperature crystallization technology enables them to be better applied in flexible display technologies [4]. Developing metal oxide semiconductors with high mobility, stability, and low cost is crucial for full-oxide backplane technology.

However, the electrical reliability issues is the main problem of high mobility metal oxide TFT such as bias temperature stress, bias illumination stress and oxygen vacancy defect control. In this study, two kind of different metal oxide TFT devices, designated as MO-1 and MO-2, were demonstrated. The field-effect mobility of MO-1 and MO-2 were higher than 30 and 40, respectively. Consideration for mass production applications, the electrical uniformity and electrical reliability of high mobility metal oxide TFTs were improved by optimized process conditions. Furthermore, we have successfully developed 13.2 and 12.6 inch AMOLED display with MO-1 and MO-2 backplane technology, respectively.

2. Experimental Section

The high mobility metal oxide TFTs were top gate self-aligned with bottom gate structure shown in Fig. 1. We deposited MO-1 and MO-2 as channel layer by using physical vapor deposition (PVD) on Gen 6 PI flexible substrate and G4.5 rigid glass substrate, respectively. The electrical and reliability characteristics of high mobility metal oxide TFTs were performed by using a semiconductor parameter keysight B1500A. The gate voltage range for Ids-Vgs measurements was set from -15 to 15 V. The positive bias temperature stress (PBTS) and negative bias temperature stress (NBTS) test conditions were ±30 V gate bias at temperature of 60 °C for 12 hours. The carrier concentration and Hall mobility for high mobility metal oxide films were analyzed by Hall measurement.

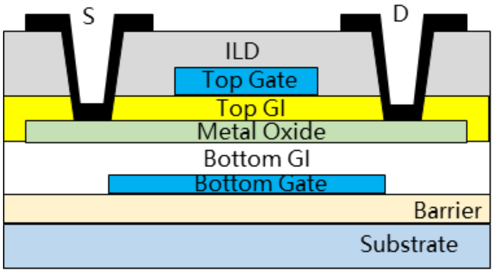

Fig. 1 Cross-section structure of self-aligned metal oxide TFTs with bottom gate.

3. Results and Discussion

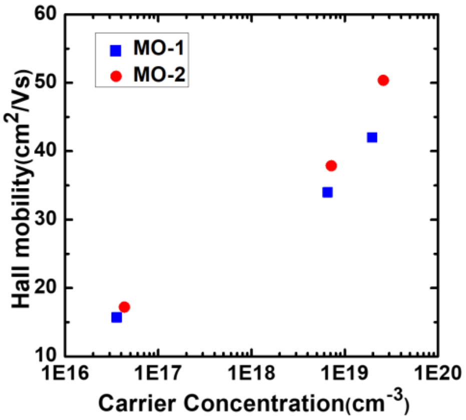

Fig. 2 Carrier concentration and Hall mobility of different metal oxide films.

The Hall measurement results of MO-1 and MO-2 were shown in Fig. 2. The Hall mobility of MO-2 film was relative higher than MO-1 film, which probably can be attributed to the polycrystalline structure of MO-2 film. Fig.3 showed the physical characteristics of MO-2 film of (a) XRD and (b) EBSD pattern. The MO-2 film exhibited a polycrystalline structure after annealing. The large grain size of MO-2 film can be obtained by optimized the process.

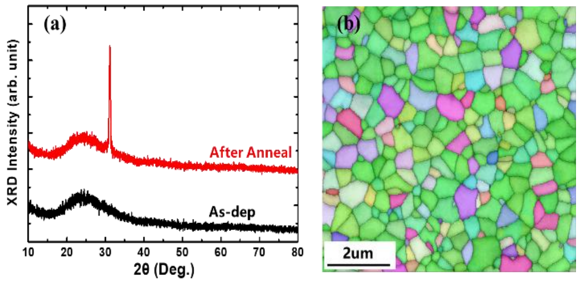

Fig. 3 (a) XRD spectra of MO-2 film before and after annealing. (b) EBSD pattern of MO-2 film after annealing.

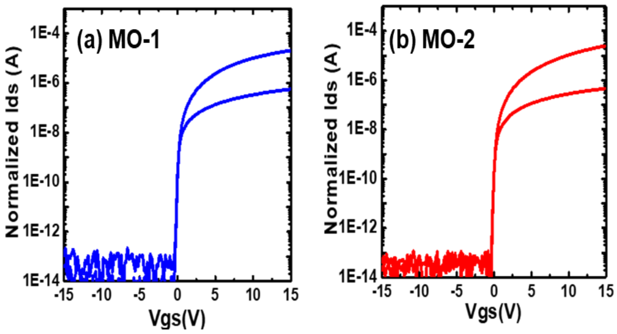

Fig. 4 Transfer curves of (a) MO-1 and (b) MO-2 metal oxide TFTs.

Fig. 4 (a) and (b) showed the transfer curves of MO-1 and MO-2 metal oxide TFT devices. The Vth values of MO-1 and MO-2 metal oxide TFT were 0.19V and 0.04V. The mobility values of MO-1 and MO-2 were 33 and 42.

Moreover, the electrical uniformity is the one of important factor for mass production evaluation. Therefore, The Vth variations of MO-1 and MO-2 TFTs were be evaluated, as shown in Fig. 5. The Vth distribution of MO-1 oxide TFTs was presented in Fig. 5(a), which demonstrated a small Vth variation (0.21V max-min) on the Gen. 6 PI/glass substrate (1500*1800mm). This result indicates that MO-1 oxide backplane technology is possible to achieve good brightness uniformity for AMOLED mass production, especially in medium-size display. The Vth distribution of MO-2 oxide TFTs was presented in Fig. 5(b). The Vth range of MO-2 oxide TFTs was 0.46V on the Gen. 4.5 glass substrate (730*920mm). The Vth distribution of MO-2 oxide TFTs probably can be further improved through the distribution of oxygen vacancy in metal oxide deposition process and the uniformity of hydrogen contents in buffer and gate insulator films.

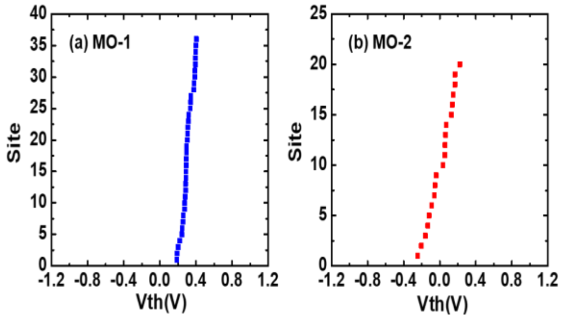

Fig. 5 The Vth distribution of (a) MO-1 and (b) MO-2 metal oxide TFTs on Gen. 6 and Gen. 4.5 glass area.

Fig. 6(a) and (b) showed the transfer characteristics of MO-1 and MO-2 oxide TFT devices under 30V gate bias stress at temperature of 60 °C as a function of stress time, respectively. After 12 hours PBTS, the positive parallel Vth shift of 0.46V and 0.8V were observed for MO-1 and MO-2 oxide TFT devices, respectively. The positive Vth shift of MO-1 and MO-2 oxide TFT can be related to the negative charge trap at GI and/or GI interface [5].Moreover, the Vth of MO-1 and MO-2 oxide TFT devices were almost no significant shift after NBTS. The Vth shift as a function of stress time under PBTS and NBTS was shown in Fig. 6(c). The MO-1 oxide TFT exhibited a small Vth shift after long tern PBTS, which can be related to the well control of oxygen vacancy defects by optimized process condition. The electrical reliability of MO-2 oxide TFTs demonstrated a larger Vth shift than MO-1 oxide TFTs, which probably due to a larger number of deep energy defects in metal oxide channel layer with higher mobility metal oxide material.

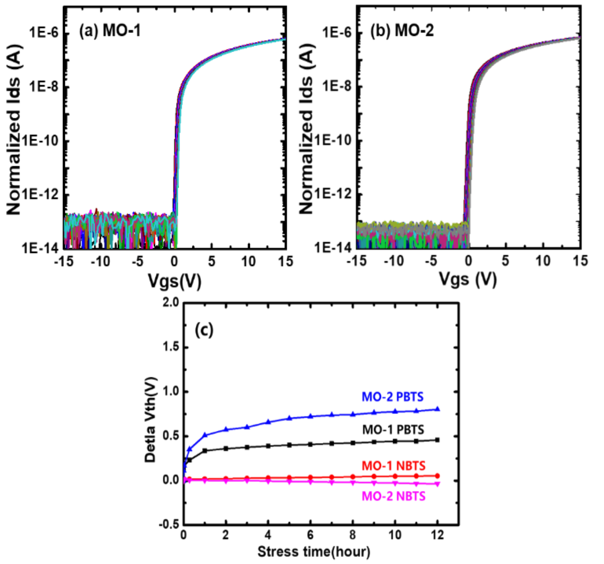

Fig. 6 The transfer curves of (a) MO-1 and (b) MO-2 oxide TFT devices under 30V gate bias stress at temperature of 60 °C as a function of stress time. (c) The Vth shift as a function of stress time under PBTS and NBTS.

Fig. 7 13.2 inch full oxide AMOLED display with high mobility MO-1 metal oxide TFT backplane technology.

Table 1. The specification of 13.2 inch panel with MO-1 metal oxide TFT backplane technology.

	Panel Specification
Panel Type	**Flexible AMOLED**
Panel Size	**13.2 inch**
Backplane	**Oxide TFT (GIP+ Pixel)**
Resolution	**2880×1920**
Pixel Pitch	**262 PPI (Real PPI)**
Refresh rate	**1~240Hz**

The 13.2 inch full oxide flexible AMOLED display with MO-1 oxide TFT backplane technology has been demonstrated successfully, as shown in Fig. 7. The detail specification of 13.2 inch AMOLED panel was shown in table 1. The 13.2 inch MO-1 full oxide flexible AMOLED display exhibited good brightness uniformity which can be attributed to the small Vth variation in Gen 6 glass area. The high mobility MO-1 metal oxide TFT backplane technology exhibited 262 PPI and wide refresh rate (1~240Hz) for middle size AMOLED display. This outcome indicates that MO-1 metal oxide TFTs is one of great potential backplane technology for large-generation AMOLED mass production.

Fig. 8 12.6 inch full oxide AMOLED display with high mobility MO-2 metal oxide TFT backplane technology.

Table 2. The specification of 12.6 inch panel with MO-2 metal oxide TFT backplane technology.

	Panel Specification
Panel Type	**Hybrid AMOLED**
Panel Size	**12.6 inch**
Backplane	**Oxide TFT (GIP+ Pixel)**
Resolution	**2880×1800**
Pixel Pitch	**273 PPI (Real PPI)**
Refresh rate	**1~240Hz**

The 12.6 inch full oxide flexible AMOLED display with MO-2 oxide TFT backplane technology has also been demonstrated successfully, as shown in Fig. 8. The detail specification of 12.6 inch AMOLED panel was shown in table 2. The high mobility MO-2 metal oxide TFT backplane technology exhibited 273 PPI and wide refresh rate (1~240Hz) for middle size AMOLED display. The MO-2 oxide TFTs exhibited higher mobility than MO-1 metal oxide TFTs, which indicating the higher potential for narrow border can be achieved by using MO-2 metal oxide TFT backplane technology.

4. Conclusions

In this paper, The 13.2 and 12.6 inch middle-size AMOLED display have been demonstrated successfully by using MO-1 and MO-2 metal oxide TFT backplane technology, respectively. We believe that the MO-1 and MO-2 metal oxide backplane technology exhibit great potential for large-generation mass production applications.

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